510 Rec'd PCT/PTO 10 AUG 1999

FORM PTO-1390 (REV 11-98)	U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER 30-508
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5) 09/367108 Unknown
INTERNATIONAL APPLICATION NO. PCT/FI98/00061	INTERNATIONAL FILING DATE 23 January 1998	PRIORITY DATE CLAIMED 14 February 1997

TITLE OF INVENTION

A STRUCTURAL PLY OF A PAPERBOARD CORE, A PAPERBOARD CORE MADE THEREOF, AND A METHOD OF IMPROVING THE STIFFNESS OF A PAPERBOARD CORE

APPLICANT(S) FOR DO/EO/US

HAAPANIEMI et al

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. A copy of the International Application as filed (35 U.S.C. 371(c)(2)).
 a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
 b. ☒ has been transmitted by the International Bureau.
 c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
 a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
 b. ☐ have been transmitted by the International Bureau.
 c. ☐ have not been made; however, the time limit for making such amendments has **NOT** expired.
 d. ☐ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. To 16. Below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
 ☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information. PTO-1449, copies of references and International Search Report

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U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
09/367108 Unknown	PCT/FI98/00061	30-508

17. ☒ The following fees are submitted:

	CALCULATIONS PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5):	
-- Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO.....$970.00	
-- International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO$840.00	
-- International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2) paid to USPTO.....$760.00	
-- International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4)$670.00	
-- International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4).....$96.00	
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 970.00
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$ 0.00

CLAIMS	NUMBER FILED		NUMBER EXTRA	RATE		
Total Claims	**20**	-20 =	0	X	$18.00	$ 0.00
Independent Claims	**3**	-3 =	0	X	$78.00	0.00
MULTIPLE DEPENDENT CLAIMS(S) (if applicable)				+$260.00		$ 0.00
				TOTAL OF ABOVE CALCULATIONS =		$ **970.00**
Reduction by ½ for filing by small entity, if applicable. A Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28).						0.00
				SUBTOTAL =		$ **970.00**
Processing fee of $130.00, for furnishing the English Translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				+		0.00
				TOTAL NATIONAL FEE =		$ **970.00**
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property				+		$ 40.00
Fee for Petition to Revive Unintentionally Abandoned Application ($1,210 – Small Entity Fee = $605)						$ 0.00
				TOTAL FEES ENCLOSED =		$ **1010.00**
					Amount to be: refunded	$
					charged	$

a. ☒ A check in the amount of $1010.00 to cover the above fees is enclosed.
b. ☐ Please charge my Deposit Account No. 14-1140 in the amount of $_____ to cover the above fees. A duplicate copy of this form is enclosed.
c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 14-1140. A duplicate copy of this form is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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NAME

27,076 REGISTRATION NUMBER

August 10, 1999 Date

09/367108
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of

HAAPANIEMI et al

Atty. Ref.: **30-508**

Serial No. **Unknown**

Group:

Filed: **August 10, 1999**

Examiner:

For: **A STRUCTURAL PLY OF A PAPERBOARD CORE, A PAPERBOARD CORE MADE THEREOF, AND A METHOD OF IMPROVING THE STIFFNESS OF A PAPERBOARD CORE**

* * * * * * * * * * *

August 10, 1999

Assistant Commissioner for Patents
Washington, DC 20231

Sir:

PRELIMINARY AMENDMENT

Prior to calculation of the filing fee and in order to place the above identified application in better condition for examination, please amend the specification and claims as follows:

IN THE SPECIFICATION

Substitute the specification on the attached sheets for the amended specification pages 1 through 17 submitted January 29, 1999.

IN THE CLAIMS

Cancel claims 1 through 17 without prejudice and substitute the following therefor:

-- 18. A paperboard core, comprising:

said paperboard core comprising a plurality of structural plies, at least one of said structural ply made by press drying in a machine having machine and cross machine directions, and having a machine direction modulus of elasticity of at least 7500 Mpa, and a cross machine direction modulus of elasticity greater than 4500.

19. A paperboard core as recited in claim 18 wherein said at least one structural ply has a modulus of elasticity in the cross machine direction of greater than 5000 Mpa.

20. A paperboard core as recited in claim 19 wherein said at least one structural ply has a modulus of elasticity in the machine direction of greater than 8000 Mpa.

21. A paperboard core as recited in claim 20 wherein said paperboard core has a wall thickness of at least 10 mm, and an inside diameter of at 70 mm; and wherein said core has a paperboard ply located in the middle thereof, said middle paperboard ply having a width selected from the group consisting essentially of: if the core inside diameter is between 73-110 mm, at least 185 mm; if the core inside diameter is between 111-144 mm, at least 205 mm; if the core inside diameter is between 145-180 mm, at least 210 mm; and if the core inside diameter is between 181-310 mm, at least 220 mm; except that the maximum ply width is (π times the core diameter.

22. A paperboard core as recited in claim 18 wherein said at least one structural ply has a modulus of elasticity in the cross machine direction of greater than 6500 Mpa, and wherein said at least one structural ply has a modulus of elasticity in the machine direction of greater than 8000 Mpa.

23. A paperboard core as recited in claim 22 wherein said paperboard core has a wall thickness of at least 10 mm, and an inside diameter of at 70 mm; and wherein said core has a paperboard ply located in the middle thereof, said middle paperboard ply having a width selected from the group consisting essentially of: if the

core inside diameter is between 73-110 mm, at least 230 mm; if the core inside diameter is between 111-144 mm, at least 230 mm; if the core inside diameter is between 145-180 mm, about 350-450 mm; and if the core inside diameter is between 181-310 mm, about 350-500 mm; except that the maximum ply width is (π times the core diameter.

24. A paperboard core comprising:

a plurality of spirally wound paperboard structural plies forming said paperboard core, and wherein at least one of said paperboard structural plies has a machine direction modulus of elasticity of at least 7500 Mpa, and a cross machine direction modulus of elasticity greater than 4500 Mpa.

25. A paperboard core as recited in claim 24 wherein said core has a wall thickness; and wherein the total thickness of said structural plies is at least 1/5 of said core wall thickness, and wherein the machine direction modulus of elasticity is greater than 8000 Mpa and the cross machine direction modulus of elasticity is greater than 6500 Mpa.

26. A paperboard core as recited in claim 25 further comprising yarn wound around said core, so that said core serves as a yarn carrier.

27. A paperboard core as recited in claim 25 further comprising thin films or foil wrapped around said core, so that said core serves as a film or foil tube.

28. A method of making a useable paperboard core using a plurality of paperboard structural plies, at least one of which has a machine direction modulus of elasticity of at least 7500 Mpa, and a cross machine direction modulus of elasticity greater than 4500 Mpa, comprising:

(a) spirally winding the structural plies into a paperboard core.

29. A method as recited in claim 28 wherein the paperboard core has a wall thickness, and wherein(a) is practiced so that the structural plies of the formed paperboard core have a thickness of at least 1/5 of the core wall thickness

30. A method as recited in claim 28 further comprising (b) winding yarn on the paperboard core, so that the core functions as a yarn carrier.

31. A method as recited in claim 28 further comprising (b) winding thin film or foil on the paperboard core, so that the core functions as a film or foil tube

32. A method as recited in claim 28 wherein (a) is practiced to produce a core having a wall thickness of at least 10 mm and an inside diameter of over 70 mm; and further comprising (b) winding a material on the paperboard core, and (c) unwinding the material from the paperboard core; and wherein (b) and (c) are practiced at a speed of at least about 200 meters/min.

33. A method as recited in claim 28 wherein the at least one structural ply is manufactured by the Condebelt process

34. A method as recited in claim 29 wherein (a) is practiced to produce a core having a wall thickness of at least 10 mm and an inside diameter of over 70 mm; and further comprising (b) winding a material on the paperboard core, and (c) unwinding the material from the paperboard core; and wherein (b) and (c) are practiced at a speed of at least about 200 meters/min.

35. A method as recited in claim 34 further comprising (b) winding yarn on the paperboard core, so that the core functions as a yarn carrier.

36. A method as recited in claim 34 further comprising (b) winding thin film or foil on the paperboard core, so that the core functions as a film or foil tube.

37. A method as recited in claim 34 wherein the at least one structural ply is manufactured by the Condebelt process.

IN THE ABSTRACT

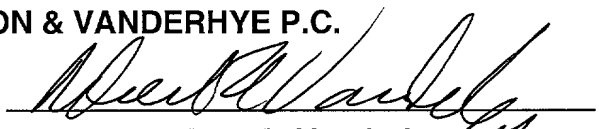
Provide what is on the attached as the Abstract.

REMARKS

A new specification is provided herewith which corresponds to the amended specification PCT prosecution plus adding the headings as preferred under U.S. law, and changing the first paragraph so that it does not refer to the preamble of claim 1, and specifically adding to the specification that which was in original claim 18, but was not specifically set forth in the specification. Early passage to issue is earnestly solicited.

Respectfully submitted,

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PRIORITY DATE 10 AUG 1999

A STRUCTURAL PLY OF A PAPERBOARD CORE, A PAPERBOARD CORE MADE THEREOF, AND A METHOD OF IMPROVING THE STIFFNESS OF A PAPERBOARD CORE

The present invention relates to a structural ply of a paperboard core, in accordance with the preamble of claim 1. The invention also relates to a spiral core comprising such a structural ply. Further, it relates to a method of improving the stiffness of a spiral paperboard core.

A spiral paperboard core is made up of a plurality of superimposed plies of paperboard by winding, glueing, and drying such.

Webs produced in the paper, film, and textile industries are usually reeled on cores for rolls. Cores made from paperboard, especially spiral cores are manufactured by glueing plies of paperboard one on top of the other and by winding them spirally in a special spiral machine. The width, thickness, and number of paperboard plies needed to form a core vary depending on the dimensions and strength requirements of the core to be manufactured. Typically, the ply width is 50 to 250 mm (in special cases about 500 mm), ply thickness about 0.2 to 1.2 mm, and the number of plies about 3 to 30 (in special cases about 50). The strength of a paperboard ply varies to comply with the strength requirement of the core. As a general rule, increasing the strength of a paperboard ply also increases its price. Generally speaking, it is therefore true to say that the stronger the core, the more expensive it is.

Paper reels used on printing presses are formed on a winding core. Almost always this winding core is a spirally wound paperboard core. In high efficiency printing presses, there is effected a so-called flying reel change towards the end of unwinding, i.e., the web for a

new paper reel is joined at full speed to the web which has been nearly unwound. A sufficiently firm and stiff core is a highly essential factor for the flying reel change to be successful.

Printing presses typically use cores of two sizes. The most usual core size has the inside diameter of 76 mm and the wall thickness of 13 or 15 mm. Today, the widest and fastest printing presses use cores with the inside diameter of 150 mm and the wall thickness of 13 mm. At the reel change, the minimum thickness of paper on the core is about 3 to 8 mm. If the core is not stiff enough, even much more paper has to be left thereon. Paperboard cores used at printing presses are typical cores of the paper industry, i.e., they are thick-walled, the wall thickness H being 10 mm or more and the inside diameter of the core being over 70 mm. Cores for the paper industry have to be thick-walled, i.e., the wall thickness has to be about 10 mm or more, e.g., in order to enable them to be clamped by chucks (chuck expansion) and in order to enable formation of a nip between the core surface and a backing roll, for the paper web to be reeled. Especially, the geometry of slitter-winders calls for a sufficient wall thickness of the cores, which is in practice 10 mm or more. Typically, such paper industry cores are used if the winding/unwinding speeds are at least about 200 m/min (=3.3 m/s).

If and, in practical circumstances, when the web speed of the printing press is not reduced for the reel change and when the size, i.e., the diameter of the paper reel diminishes during unwinding thereof, the speed of rotation of the diminishing reel increases to a considerably high rate.

The tendency has been towards wider and wider as well as faster and faster printing presses. Transferring to wide

printing presses, i.e., those with long cores, and high running speeds, may result in that the rest reel, i.e., the paperboard core + the paper web to be left thereon, will get into its natural vibration range during the reel change, consequently shaking. This may lead to a costly web break or even to an explosion of the rest reel into pieces, thereby causing an extreme safety risk.

Such a situation is typical to wide and fast rotogravure presses. Rotogravure printing is a highly efficient printing mode, utilizing wide and fast printing presses and big reels. Also the fastest and widest catalogue presses may end up in a similar situation. With catalogue presses, this is partly also due to the fact that the stiffness factor of the paper roll supporting system, dependent on the chucks, is usually weaker than in high efficiency rotogravure presses.

In rotogravure presses, where the stability problem in unwinding is current, conditions are typically as follows.

With 2.45 m wide printing presses, cores with inside diameter of 76 mm are used. In special cases, when usually a larger amount of produced paper is required, printing presses of at most 2.65 m in width can be used together with cores having the inside diameter of 76 mm. If the rest reel were run near to the usual minimum amount of residual paper with these running parameters, the safety factor as to getting into the vibration range would be absolutely too small. In order that safe handling of the rest reel can be ensured, the amount of residual paper has to be grown from the earlier minimum of about 3 - 8 mm to as much as 15 mm. This naturally causes a great economic loss in form of wasted paper. The web speed at printing is here about 14 m/s.

When the inside diameter of the core is 150 mm, the printing press widths usually exceed the above values (cores having the inside diameter of 150 mm are, however, applicable with the above printing press widths). The printing press widths are typically 3.08 m, 3.18 m, or 3.28 m. The printing speeds with these machines are the same as mentioned above.

The new generation of rotogravure presses will again be wider and faster than before, estimates of a combination of width and web speed of 3.68 m and 16 m/s or alternatively 3.08 m and 20 m/s or 3.18 m and 25 m/s have been presented. By early 1997, however, such new generation rotogravure presses have not yet been manufactured.

In the widest printing presses, which require a wider/faster web, the inside diameter of the core has been changed to 150 mm in order to solve the vibration problem. So far, this arrangement has functioned well. Now, the same problem as with earlier machines, until transferring to 150 mm cores, will be faced again with the running parameters of the new machines being designed. In other words, the risky range of natural vibration of the rest reel will be entered again.

For this reason, the stiffness of the core has to be grown in one way or another, in order that an increase in the inside diameter of the core could be avoided. The arrangement of increasing the inside diameter of the core has been considered a most undesirable solution in the production chain.

As discussed above, a spiral paperboard core is manufactured by winding narrow paperboard plies spirally around a mandrel. The paperboard of which the plies to be wound are cut off has been manufactured with a board machine. The selection of the interior and exterior plies of the

core is usually (not always) based on other grounds than the selection of the structural plies. Therefore, the strength properties of the interior and exterior plies are not often the same as those of other plies of the core. These other plies, usually located between the outer plies of the core, are called structural plies because their properties determine the final strength and quality class and other properties of the core. In those cases in which the end use of the core does not set any special demands on the exterior or interior plies (or under-exterior plies attached to them), the entire core may be constructed of these above-identified structural plies. In manufacturing of paperboard, it is an ambition to get its strength properties as homogeneous as possible. So-called squareness is the term used in this context, and its theoretical low limit, which is 1, is striven for. The longitudinal (= machine direction) strength of square paperboard as well as its elasticity modulus are the same as its corresponding values in the cross machine direction. In board machine arrangements of prior art, paperboard is, however, essentially stronger in the machine direction (typically 1.6 - 2.7 times stronger) than in the cross machine direction. This applies to the elasticity modulus of paperboard as well. As to the core stiffness, the axial stiffness factor of the core is determining. Due to the structure of a spirally wound core, the stiffness factor of paperboard in the machine direction (bigger) becomes more or less circumferential and the stiffness factor of paperboard in the cross machine direction (smaller) more or less axial.

By optimizing the ratio of paperboard in the machine direction to paperboard in the cross machine direction and by adjusting the structure of a spirally wound core (winding angles), it is possible to influence on the situation to some extent. However, with conventional board machines and conventional spiral machines, the

chances are quite limited, and not adequate for solving the problem.

Rotogravure cores are divided into two categories in accordance with their strength requirement, i.e., into a lower and a higher strength class. The elasticity moduli of conventional rotogravure cores of the lower strength class are on the level of 3300 to 4000 MPa. The elasticity moduli of commercial grades made from conventional materials but belonging to the higher strength class are on the level of 4200 to 4800 MPa. With special measures, these values can be marginally exceeded. The reel weights and printing press widths in rotogravure presses determine from which of the two strength classes paperboard cores are selected.

The levels of elasticity moduli of the raw materials for the core are dependent on the raw material for the paperboard ply to be used, on the manufacturing method, and on the orientation ratio (strength parameters of the ratio of paperboard in the machine direction to paperboard in the cross machine direction). The elasticity moduli of typical paperboard materials for rotogravure cores, which have expedient squareness, are about 6000 MPa in the machine direction and about 3000 MPa in the cross machine direction in the lower strength class. The corresponding values for the higher strength class materials are about 6500 to 7500 MPa in the machine direction and about 3600 to 4000 MPa in the cross machine direction.

A prior art patent document US 5,505,395 describes a typical prior art core for the higher strength class, used e.g. for rotogravure cores. The elasticity moduli of the plies in one solution, described in this patent document are about 10900 Mpa in the machine direction and about 3660 Mpa in the cross machine direction (Table I).

A prior art patent document US 5,167,994 describes a reusable, dimensionally stable, lightweight, multi-layer tubular core. A water barrier is embedded between the outermost layer or layers and the central or intermediate layers of fibrous material. Similarily, a water barrier is embedded between the innermost layer or layers of fibrous material and the central or intermediate layers. The vapour barrier layers prevent the fibrous materials used in constructing primarily intermediate layers of the tube from absorbing moisture from atmosphere. This minimizes changes in the dimensions of the tube with changes in ambient humidity.

A prior art patent document US 4,675,079 describes an improved multi-nip suction press with a four roller closed train. This document represents one of the prior art drying apparatuses.

An object of the present invention is to provide a structural ply of a novel type and improved applicability for a spiral paperboard core. Another object of the present invention is to provide a spiral paperboard core comprising at least one such structural ply and having improved strength properties. As the structural plies in accordance of the invention are superior to prior art structural plies, it is worthwhile optimizing their share of the core wall thickness and location in the core wall. As discussed above, the quality class of the raw materials for cores and consequently also the quality class of cores goes hand in hand with the price paid/received for them.

A still further object of the present invention is to solve problems related to presently used spiral cores discussed above, and to provide a spiral paperboard core, which meets e.g. the strength requirements of cores, set

by the running parameters of new printing presses. The arrangements according to the present invention are also applicable to other places where especially high stiffness is required.

These objects are achieved with the arrangements in accordance with the accompanying claims.

Based on tests we have performed, we have found that sufficiently strong cores are provided for printing presses of the new generation, and cores stronger than before are provided for existing printing presses when, in accordance with the present invention, the cross machine direction (CD) elasticity modulus E of a structural ply of a spiral paperboard core is substantially higher than 4500 MPa. Further, the machine direction (MD) elasticity modulus E of the structural ply is preferably substantially higher than 7500 MPa.

These new type paperboard cores of the present invention can be manufactured by using, either solely or partly, structural plies in accordance with the invention. The paperboard for these structural plies is manufactured, e.g., by what is called a press drying method.

Paperboard based on press drying can be manufactured by a board machine, utilizing a prior art process called Condebelt. The inventor of this Condebelt process is Jukka Lehtinen of Tampella LTd, Finland. There is at present (1997) only one machine (made by Valmet LTd) in the world utilising this Condebelt press drying process; Pankakoski Boards Oy Ltd, a member of the Enso Group (Paperi ja Puu - Paper and Timber VOL 77 /NO 3/1995, p.69). Structural plies manufactured with other appropriate methods and meeting the strength requirements according to the invention can also be utilized in constructing a paperboard core. In Dennis Gunderson's review

article in "Paperi ja puu - Paper and Timber" Vol. 74/NO 5/1992, pp. 412-418 on p. 415 Donald Sparkes has defined press drying as being "any process which simultaneously applies heat and perpendicular pressure to the moist paper in excess of that applied by the combination of a dryer cylinder and fabric, but excluding the commercially well established combination of Yankee cylinder and pressure rolls". Only one of the sixteen developments reviewed by Sparkes is directed toward reproducing the conditions of static press drying; that is Lehtine's Condebelt design.

As press drying is an efficient process, it is possible to increase the elasticity moduli of structural plies by that method, and the machine direction elasticity modulus of the above-mentioned structural plies of a rotogravure core of the lower strength class can be raised to a level of at least about 7500 - 10000 MPa, and with winding angles of 15 to 35° which are usually used, the elasticity modulus in the cross machine direction, which is very important, can be raised to a level of about 4500 - 5000 MPa. For example, the test result showing the elasticity modulus of 4800 MPa in the cross machine direction represents a fairly high standard in this strength class. As to cores of the higher strength level in accordance with the present invention, they correspond to the higher or better strength level of rotogravure cores. When structural plies according to the invention and manufactured from the better quality press drying material (e.g., with the so-called Condebelt method) are used, the machine direction elasticity modulus can be raised to a level of about 10000 - 12000 MPa, and the elasticity modulus in the cross machine direction to a level of about 5000 - 8000 MPa. Test results showing, e.g., the levels of structural ply elasticity moduli of 5500 MPa and 6500 MPa in the cross machine direction represent a fairly high

standard in this strength class.

Use of the new structural ply as described in the invention meets the stiffness requirement of cores to be used in rotogravure presses of the new generation without a need to change the core structure in any other way except for the raw material.

Thus, the elasticity modulus of the cores of the presently used lower strength class cores can be raised to a level of at least about 5000 - 6000 MPa by utilizing arrangements of the invention. For example, a test result showing the level of elasticity modulus of at least about 5500 MPa represents a fairly high standard in this strength class. The elasticity modulus of the higher strength class cores may be raised to a level of at least about 6000 - 6500 - 7000 MPa and even higher, which is adequate for meeting the requirements set by the new generation of rotogravure presses.

As can be seen, the values of the elasticity modulus of cores made up of paperboard plies according to the invention well suffice for the strength requirements of the above-mentioned rotogravure presses.

Use of paperboard cores according to the invention is not exclusively intended to the exemplified paperboard cores of the new generation of rotogravure presses. They may be used in every place where a higher stiffness is required of cores than usually. Such especially stiff cores are needed, for example, in rolling up carpets. Such carpet cores are subjected to especially long-lasting stresses because the carpet to be rolled around the core does not support the core, unlike e.g. in reeling paper. The inside diameter of the core can naturally be something else than the above-mentioned dimensions 76 and 150 mm, which are typical core diameters in rotogravure presses

today.

By employing arrangements of the present invention in manufacturing rotogravure cores, the use range of cores having the inside diameter of 76 mm can be safely extended towards rotogravure presses, which are faster and wider than today. Thus, the arrangements according to the present invention provide answers to the challenges brought by completely new rotogravure presses as well as improve the economy of existing rotogravure presses.

Press drying (e.g. Condebelt) materials mentioned above may also be used together with conventional core boards to provide a multigrade construction in situations where the elasticity modulus need not be quite as high and where it is desirable to save material due to either limited availability or costs. In such cases, a structural ply having a high elasticity modulus is used, e.g., in places where strength is a strategic factor, and conventional, prior art structural plies of adequate competence are used elsewhere.

The stiffness of a spirally wound multigrade paperboard core may be improved by constructing the core so that at least one of the structural plies is in accordance with the present invention, having the cross machine direction elasticity modulus of at least 4500 MPa. Further, it is especially advantageous that the machine direction elasticity modulus of the structural ply is at least 7500 MPa. Preferably, the share of structural plies in accordance with the invention is at least about 1/5 of the core wall thickness. Other potential structural plies may comply with prior art. As the structural plies of a paperboard core, in accordance with the invention, are superior to structural plies of prior art, it is worthwhile optimizing the share of the former of the core wall thickness as well as their location in the core wall. As

discussed above, the quality class of core raw materials and consequently also the quality class of finished cores usually goes hand in hand with the price paid/received for them. Therefore, the optimization is well grounded both from the core manufacturer's and the customer's point of view.

A structural ply in accordance with the invention, a paperboard core made thereof, and a method of improving the stiffness of the paperboard core are described in greater detail in the following, by way of example, with reference to the accompanying drawings, in which

Fig. 1 shows graphically, as a function of the winding angle α, elasticity modulus values for paperboard cores made up of different paperboard plies,
Fig. 2 illustrates the definition of the winding angle α, and
Fig. 3 illustrates the decreases in the inside diameter of a core, calculated with different winding angles α for two different types of paperboard.

Fig. 1 enclosed is a graphical illustration, presented as a function of a winding angle α (average winding angle), of elasticity modulus values of cores manufactured by using paperboard plies in accordance with the present invention, such cores being, e.g., rotogravure cores, used in the paper, film, and textile industries, said elasticity modulus values being compared with corresponding elasticity modulus values of prior art conventional cores of the higher strength class. As discussed above, with the winding angles of about 15 - 35°, which are usually used in spiral cores, the cross machine direction elasticity modulus is of highly essential effect on the total elasticity modulus of a finished spiral core. The definition of the winding angle α (average winding angle)

of a paperboard ply, in connection with the present invention, is set forth in Fig. 2. The winding angle α (average winding angle) refers to the acute angle α between the direction transverse to the paperboard core axis and the edge of the paperboard ply. In Fig. 1, the three-point dashed line refers to a typical prior art rotogravure core of the lower strength class. The uniform dashed line again refers to a typical prior art rotogravure core of the higher strength class. In this core, the paperboard used as core material is as square as possible with regard to its orientation ratio, i.e., the numeric value of the orientation ratio is small. The dotted and dashed line refers to a rotogravure core constructed of structural plies of the invention and the solid line to another rotogravure core made up of structural plies of the invention.

When reeling thin films or yarns around a spirally wound paperboard core, the material to be reeled causes a radial compressior stress on the core, the inside diameter of the core becoming subject to the compression which provides a deformation therein, i.e., a decrease in the inside diameter of the core. In practical situations, this causes problems with certain types of winding chucks, when the core tends to stick thereto.

When reeling yarns around a spirally wound paperboard core or a yarn carrier, the reeling environment may still be wet, in practice. This adds to the tendency of the inside dimensions of the core to deform and the core to stick to the winding center.

We have discovered that it is possible to considerably weaken the tendency of the inside diameter of the core to decrease, by using structural plies according to the invention in constructing such cores, as can be seen from the accompanying Fig. 3.

Fig. 3 shows the decreases of the inside diameter of the core, calculated for two different paperboard grades by using different winding angles α (average winding angle). The orientation ratio of the paperboard commonly used today, which paperboard is marked with a circle, was about 1.6 in the test. The machine direction (MD) elasticity modulus was about 7000 MPa and the cross machine direction (CD) elasticity modulus about 3000 MPa. The orientation ratio of the paperboard manufactured by press drying (e.g. Condebelt paperboard), which paperboard is marked with a triangle, was about 1.8 in the test, and the machine direction (MD) elasticity modulus was about 11000 MPa, and the cross machine direction (CD) elasticity modulus about 6000 MPa.

CLAIMS

1. A structural ply of a paperboard core, the machine direction (MD) elasticity modulus E of said structural ply being at least 7000 Mpa, **characterized** in that the structural ply is manufactured with a press drying method and that the cross machine direction (CD) elasticity modulus E of the structural ply is higher than 4500 Mpa.

2. A structural ply as recited in claim 1, **characterized** in that the cross machine direction (CD) elasticity modulus E of the structural ply is higher than 4800 MPa and preferably higher than 5000 MPa.

3. A structural ply as recited in claim 1, **characterized** in that the cross machine direction (CD) elasticity modulus E of the structural ply is higher than 5500 MPa, preferably higher than 6000 MPa, and more preferably over 6500 MPa.

4. A structural ply as recited in any of the preceding claims 1 to 3, **characterized** in that the machine direction (MD) elasticity modulus E of the structural ply is further substantially higher than 8000 MPa.

5. A structural ply as recited in any of the claims 1 to 4, **characterized** in that the structural ply is manufactured with a Condebelt process, which is a press drying method.

6. A paperboard core comprising a structural ply as recited in any of the preceding claims, the elasticity modulus E of the paperboard core being at least 5000 MPa, preferably over 5500 MPa, more preferably over 6000 MPa.

7. A spirally wound paperboard core, **characterized** in

that the paperboard core comprises structural plies, the cross machine direction (CD) elasticity modulus of at least one of which structural plies is over 4500 MPa, preferably over 5000 MPa, and the machine direction (MD) elasticity modulus at least 7500 MPa, preferably over 8000 MPa.

8. A spirally wound paperboard core as recited in claim 7, **characterized** in that the paperboard core comprises structural plies, the total thickness of the structural plies being preferably at least 1/5 of the core wall thickness and the cross machine direction (CD) elasticity modulus of the structural plies being at least 4500 MPa, preferably over 5000 MPa, and the machine direction (MD) elasticity modulus of the structural plies being at least 7800 MPa, preferably over 8000 MPa.

9. A method of improving the stiffness of a spirally wound paperboard core, **characterized** in that the paperboard core is made up of structural plies, the cross machine direction (CD) elasticity modulus of at least one of which structural plies is at least 4500 MPa, preferably over 5000 MPa, and the machine direction (MD) elasticity modulus at least 7800 MPa, preferably over 8000 MPa.

10. A method as recited in claim 9, of improving the stiffness of a spirally wound paperboard core, **characterized** in that the paperboard core is made up of structural plies the total thickness of the structural plies being preferably at least 1/5 of the core wall thickness and the cross machine direction (CD) elasticity modulus of the structural plies being at leat 4500 MPa, preferably over 5000 MPa, and the machine direction (MD) elasticity modulus at least 7800 MPa, preferably over 8000 MPa.

11. A paperboard core as recited in any of the preceding claims 6 to 8, **characterized** in that the paperboard core

is made up of structural plies, the machine direction elasticity modulus of the structural plies being at least 9000 MPa.

12. Use of a paperboard core as recited in any of the claims 6 to 8 as a yarn carrier.

13. Use of a paperboard core as recited in claim 11 as a yarn carrier.

14. Use of a paperboard core as recited in any of the claims 6 to 8 as a tube for thin films and foils.

15. Use of a paperboard core as recited in claim 11 as a tube for thin films and foils.

16. Use of a paperboard core as recited in claims 6 to 8 or in claim 11 as a thick-walled paper industry core, the wall thickness H thereof being at least 10 mm and the inside diameter over 70 mm, such cores being used with unwinding/winding speeds of at least about 200 m/min (= 3.3 m/s).

17. A core as recited in claims 6 to 8 or in claim 11, **characterized** in that the paperboard core is a thick-walled paper industry core, the wall thickness H thereof being at least 10 mm and the inside diameter over 70 mm, such cores being used with unwinding/winding speeds of at least about 200 m/min (= 3.3 m/s), the width of the paperboard ply located in the middle the core being

- with cores having the inside diameter of 73 mm to 110 mm,
at least 185 mm, preferably over 210 mm, and more preferably over 230 mm,
- with cores having the inside diameter of 111 mm to 144 mm,
at least 205 mm, preferably over 210 mm, and more prefer-

ably over 230 mm,

- with cores having the inside diameter of 145 mm to 180 mm,

at least 210 mm, preferably over 250 mm, and more preferably 350 mm to 450 mm,

- and with cores having the inside diameter of 181 mm to 310 mm,

at least 220 mm, preferably over 250 mm, and more preferably 350 to 500 mm, but

at most the maximum ply width L_{max} of each core of a certain width, where L_{max} = (π) x (core diameter in the specific point).

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A STRUCTURAL PLY OF A PAPERBOARD CORE, A PAPERBOARD CORE MADE THEREOF, AND A METHOD OF IMPROVING THE STIFFNESS OF A PAPERBOARD CORE

CROSS REFERENCE TO RELATED APPLICATION

This application is a US National Phase of PCT/FI/98/00061, the disclosure of which is incorporated by reference herein.

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates to a structural ply of a paperboard core, and particularly made by press drying in a machine having machine and cross machine directions. The invention also relates to a spiral core comprising such a structural ply. Further, it relates to a method of improving the stiffness of a spiral paperboard core.

A spiral paperboard core is made up of a plurality of superimposed plies of paperboard by winding, gluing, and drying such.

Webs produced in the paper, film, and textile industries are usually reeled on cores for rolls. Cores made from paperboard, especially spiral cores are manufactured by glueing plies of paperboard one on top of the other and by winding them spirally in a special spiral machine. The width, thickness, and number of paperboard plies needed to form a core vary depending on the dimensions and strength requirements of the core to be manufactured. Typically, the ply width is 50 to 250 mm (in special cases about 500 mm), ply thickness about 0.2 to 1.2 mm, and the number of plies about 3 to 30 (in special cases about 50). The strength of a paperboard ply varies to comply with the strength requirement of the core. As a general rule, increasing the strength of a paperboard ply also increases its price. Generally speaking, it is therefore true to say that the stronger the core, the more expensive it is.

Paper reels used on printing presses are formed on a winding core. Almost always this winding core is a spirally wound paperboard core. In high efficiency printing presses, there is effected a so-called flying reel change towards the end of unwinding, i.e., the web for a new paper reel is joined at full speed to the web which has been nearly unwound. A

sufficiently firm and stiff core is a highly essential factor for the flying reel change to be successful.

Printing presses typically use cores of two sizes. The most usual core size has the inside diameter of 76 mm and the wall thickness of 13 or 15 mm. Today, the widest and fastest printing presses use cores with the inside diameter of 150 mm and the wall thickness of 13 mm. At the reel change, the minimum thickness of paper on the core is about 3 to 8 mm. If the core is not stiff enough, even much more paper has to be left thereon. Paperboard cores used at printing presses are typical cores of the paper industry, i.e., they are thick-walled, the wall thickness H being 10 mm or more and the inside diameter of the core being over 70 mm. Cores for the paper industry have to be thick-walled, i.e., the wall thickness has to be about 10 mm or more, e.g., in order to enable them to be clamped by chucks (chuck expansion) and in order to enable formation of a nip between the core surface and a backing roll, for the paper web to be reeled. Especially, the geometry of slitter-winders calls for a sufficient wall thickness of the cores, which is in practice 10 mm or more. Typically, such paper industry cores are used if the winding/unwinding speeds are at least about 200 m/min (=3.3 m/s).

If and, in practical circumstances, when the web speed of the printing press is not reduced for the reel change and when the size, i.e., the diameter of the paper reel diminishes during unwinding thereof, the speed of rotation of the diminishing reel increases to a considerably high rate.

The tendency has been towards wider and wider as well as faster and faster printing presses. Transferring to wide printing presses, i.e., those with long cores, and high running speeds, may result in that the rest reel, i.e., the paperboard core + the paper web to be left thereon, will get into its natural vibration range during the reel change, consequently shaking. This may lead to a costly web break or even to an explosion of the rest reel into pieces, thereby causing an extreme safety risk.

Such a situation is typical to wide and fast rotogravure presses. Rotogravure printing is a highly efficient printing mode, utilizing wide and fast printing presses and big reels. Also the fastest and widest catalogue presses may end up in a similar situation. With catalogue presses, this is partly also due to the fact that the stiffness factor of the paper

roll supporting system, dependent on the chucks, is usually weaker than in high efficiency rotogravure presses.

In rotogravure presses, where the stability problem in unwinding is current, conditions are typically as follows.

With 2.45 m wide printing presses, cores with inside diameter of 76 mm are used. In special cases, when usually a larger amount of produced paper is required, printing presses of at most 2.65 m in width can be used together with cores having the inside diameter of 76 mm. If the rest reel were run near to the usual minimum amount of residual paper with these running parameters, the safety factor as to getting into the vibration range would be absolutely too small. In order that safe handling of the rest reel can be ensured, the amount of residual paper has to be grown from the earlier minimum of about 3 - 8 mm to as much as 15 mm. This naturally causes a great economic loss in form of wasted paper. The web speed at printing is here about 14 m/s.

When the inside diameter of the core is 150 mm, the printing press widths usually exceed the above values (cores having the inside diameter of 150 mm are, however, applicable with the above printing press widths). The printing press widths are typically 3.08 m, 3.18 m, or 3.28 m. The printing speeds with these machines are the same as mentioned above.

The new generation of rotogravure presses will again be wider and faster than before, estimates of a combination of width and web speed of 3.68 m and 16 m/s or alternatively 3.08 m and 20 m/s or 3.18 m and 25 m/s have been presented. By early 1997, however, such new generation rotogravure presses have not yet been manufactured.

In the widest printing presses, which require a wider/ faster web, the inside diameter of the core has been changed to 150 mm in order to solve the vibration problem. So far, this arrangement has functioned well. Now, the same problem as with earlier machines, until transferring to 150 mm cores, will be faced again with the running parameters of the new machines being designed. In other words, the risky range of natural vibration of the rest reel will be entered again.

For this reason, the stiffness of the core has to be grown in one way or another, in order that an increase in the inside diameter of the core could be avoided. The

arrangement of increasing the inside diameter of the core has been considered a most undesirable solution in the production chain.

As discussed above, a spiral paperboard core is manufactured by winding narrow paperboard plies spirally around a mandrel. The paperboard of which the plies to be wound are cut off has been manufactured with a board machine. The selection of the interior and exterior plies of the core is usually (not always) based on other grounds than the selection of the structural plies. Therefore, the strength properties of the interior and exterior plies are not often the same as those of other plies of the core. These other plies, usually located between the outer plies of the core, are called structural plies because their properties determine the final strength and quality class and other properties of the core. In those cases in which the end use of the core does not set any special demands on the exterior or interior plies (or under-exterior plies attached to them), the entire core may be constructed of these above-identified structural plies. In manufacturing of paperboard, it is an ambition to get its strength properties as homogeneous as possible. So-called squareness is the term used in this context, and its theoretical low limit, which is 1, is striven for. The longitudinal (= machine direction) strength of square paperboard as well as its elasticity modulus are the same as its corresponding values in the cross machine direction. In board machine arrangements of prior art, paperboard is, however, essentially stronger in the machine direction (typically 1.6 - 2.7 times stronger) than in the cross machine direction. This applies to the elasticity modulus of paperboard as well. As to the core stiffness, the axial stiffness factor of the core is determining. Due to the structure of a spirally wound core, the stiffness factor of paperboard in the machine direction (bigger) becomes more or less circumferential and the stiffness factor of paperboard in the cross machine direction (smaller) more or less axial.

By optimizing the ratio of paperboard in the machine direction to paperboard in the cross machine direction and by adjusting the structure of a spirally wound core (winding angles), it is possible to influence on the situation to some extent. However, with conventional board machines and conventional spiral machines, the chances are quite limited, and not adequate for solving the problem.

Rotogravure cores are divided into two categories in accordance with their strength requirement, i.e., into a lower and a higher strength class. The elasticity moduli of

conventional rotogravure cores of the lower strength class are on the level of 3300 to 4000 MPa. The elasticity moduli of commercial grades made from conventional materials but belonging to the higher strength class are on the level of 4200 to 4800 MPa. With special measures, these values can be marginally exceeded. The reel weights and printing press widths in rotogravure presses determine from which of the two strength classes paperboard cores are selected.

The levels of elasticity moduli of the raw materials for the core are dependent on the raw material for the paperboard ply to be used, on the manufacturing method, and on the orientation ratio (strength parameters of the ratio of paperboard in the machine direction to paperboard in the cross machine direction). The elasticity moduli of typical paperboard materials for rotogravure cores, which have expedient squareness, are about 6000 MPa in the machine direction and about 3000 MPa in the cross machine direction in the lower strength class. The corresponding values for the higher strength class materials are about 6500 to 7500 MPa in the machine direction and about 3500 to 4000 MPa in the cross machine direction.

A prior art patent document US 5,505,395 describes a typical prior art core for the higher strength class, used e.g. for rotogravure cores. The elasticity moduli of the plies in one solution, described in this patent document are about 10900 Mpa in the machine direction and about 3660 Mpa in the cross machine direction (Table I).

A prior art patent document US 5,167,994 describes a reusable, dimensionally stable, lightweight, multi-layer tubular core. A water barrier is embedded between the outermost layer or layers and the central or intermediate layers of fibrous material. Similarily, a water barrier is embedded between the innermost layer or layers of fibrous material and the central or intermediate layers. The vapour barrier layers prevent the fibrous materials used in constructing primarily intermediate layers of the tube from absorbing moisture from atmosphere. This minimizes changes in the dimensions of the tube with changes in ambient humidity.

A prior art patent document US 4,675,079 describes an improved multi-nip suction press with a four roller closed train. This document represents one of the prior art drying apparatuses.

An object of the present invention is to provide a structural ply of a novel type and improved applicability for a spiral paperboard core. Another object of the present invention is to provide a spiral paperboard core comprising at least one such structural ply and having improved strength properties. As the structural plies in accordance of the invention are superior to prior art structural plies, it is worthwhile optimizing their share of the core wall thickness and location in the core wall. As discussed above, the quality class of the raw materials for cores and consequently also the quality class of cores goes hand in hand with the price paid/received for them.

A still further object of the present invention is to solve problems related to presently used spiral cores discussed above, and to provide a spiral paperboard core, which meets e.g. the strength requirements of cores, set by the running parameters of new printing presses. The arrangements according to the present invention are also applicable to other places where especially high stiffness is required.

These objects are achieved with the arrangements in accordance with the accompanying claims.

Based on tests we have performed, we have found that sufficiently strong cores are provided for printing presses of the new generation, and cores stronger than before are provided for existing printing presses when, in accordance with the present invention, the cross machine direction (CD) elasticity modulus E of a structural ply of a spiral paperboard core is substantially higher than 4500 MPa. Further, the machine direction (MD) elasticity modulus E of the structural ply is preferably substantially higher than 7500 MPa.

These new type paperboard cores of the present invention can be manufactured by using, either solely or partly, structural plies in accordance with the invention. The paperboard for these structural plies is manufactured, e.g., by what is called a press drying method.

Paperboard based on press drying can be manufactured by a board machine, utilizing a prior art process called Condebelt. The inventor of this Condebelt process is Jukka Lehtinen of Tampella LTd, Finland. There is at present (1997) only one machine (made by Valmet LTd) in the world utilizing this Condebelt press drying process; Pankakoski Boards Oy Ltd, a member of the Enso Group (Paperi ja Puu – Paper and Timber VOL 77 /NO 3/1995, p.69). Structural plies manufactured with other appropriate

methods and meeting the strength requirements according to the invention can also be utilized in constructing a paperboard core. In Dennis Gunderson's review article in "Paperi ja puu - Paper and Timber" Vol. 74/NO 5/1992, pp. 412-418 on p. 415 Donald Sparkes has defined press drying as being "any process which simultaneously applies heat and perpendicular pressure to the moist paper in excess of that applied by the combination of a dryer cylinder and fabric, but excluding the commercially well established combination of Yankee cylinder and pressure rolls". Only one of the sixteen developments reviewed by Sparkes is directed toward reproducing the conditions of static press drying; that is Lehtine's Condebelt design.

As press drying is an efficient process, it is possible to increase the elasticity moduli of structural plies by that method, and the machine direction elasticity modulus of the above-mentioned structural plies of a rotogravure core of the lower strength class can be raised to a level of at least about 7500 - 10000 MPa, and with winding angles of 15 to 35° which are usually used, the elasticity modulus in the cross machine direction, which is very important, can be raised to a level of about 4500 - 5000 MPa. For example, the test result showing the elasticity modulus of 4800 MPa in the cross machine direction represents a fairly high standard in this strength class. As to cores of the higher strength level in accordance with the present invention, they correspond to the higher or better strength level of rotogravure cores. When structural plies according to the invention and manufactured from the better quality press drying material (e.g., with the so-called Condebelt method) are used, the machine direction elasticity modulus can be raised to a level of about 10000 - 12000 MPa, and the elasticity modulus in the cross machine direction to a level of about 5000 - 8000 MPa. Test results showing, e.g., the levels of structural ply elasticity moduli of 5500 MPa and 6500 MPa in the cross machine direction represent a fairly high standard in this strength class.

Use of the new structural ply as described in the invention meets the stiffness requirement of cores to be used in rotogravure presses of the new generation without a need to change the core structure in any other way except for the raw material.

Thus, the elasticity modulus of the cores of the presently used lower strength class cores can be raised to a level of at least about 5000 - 6000 MPa by utilizing arrangements of the invention. For example, a test result showing the level of elasticity modulus of at

least about 5500 MPa represents a fairly high standard in this strength class. The elasticity modulus of the higher strength class cores may be raised to a level of at least about 6000 - 6500 - 7000 MPa and even higher, which is adequate for meeting the requirements set by the new generation of rotogravure presses.

As can be seen, the values of the elasticity modulus of cores made up of paperboard plies according to the invention well suffice for the strength requirements of the above-mentioned rotogravure presses.

Use of paperboard cores according to the invention is not exclusively intended to the exemplified paperboard cores of the new generation of rotogravure presses. They may be used in every place where a higher stiffness is required of cores than usually. Such especially stiff cores are needed, for example, in rolling up carpets. Such carpet cores are subjected to especially long-lasting stresses because the carpet to be rolled around the core does not support the core, unlike e.g. in reeling paper. The inside diameter of the core can naturally be something else than the above-mentioned dimensions 76 and 150 mm, which are typical core diameters in rotogravure presses today.

By employing arrangements of the present invention in manufacturing rotogravure cores, the use range of cores having the inside diameter of 76 mm can be safely extended towards rotogravure presses, which are faster and wider than today. Thus, the arrangements according to the present invention provide answers to the challenges brought by completely new rotogravure presses as well as improve the economy of existing rotogravure presses.

Press drying (e.g. Condebelt) materials mentioned above may also be used together with conventional core boards to provide a multigrade construction in situations where the elasticity modulus need not be quite as high and where it is desirable to save material due to either limited availability or costs. In such cases, a structural ply having a high elasticity modulus is used, e.g., in places where strength is a strategic factor, and conventional, prior art structural plies of adequate competence are used elsewhere.

The stiffness of a spirally wound multigrade paperboard core may be improved by constructing the core so that at least one of the structural plies is in accordance with the present invention, having the cross machine direction elasticity modulus of at least 4500 MPa. Further, it is especially advantageous that the machine direction elasticity modulus of

the structural ply is at least 7500 MPa. Preferably, the share of structural plies in accordance with the invention is at least about 1/5 of the core wall thickness. Other potential structural plies may comply with prior art. As the structural plies of a paperboard core, in accordance with the invention, are superior to structural plies of prior art, it is worthwhile optimizing the share of the former of the core wall thickness as well as their location in the core wall. As discussed above, the quality class of core raw materials and consequently also the quality class of finished cores usually goes hand in hand with the price paid/received for them. Therefore, the optimization is well grounded both from the core manufacturer's and the customer's point of view.

Preferably, paperboard core is a thick-walled paper industry core, the wall thickness H thereof being at least 10 mm and th einsdie diameter over 70 mm, such cores being used with unwinding and winding speeds of at least about 200 m/min (= 3.3 m/s), the width of the paperboard ply located in the middle the core being

-- with cores having the inside diameter of 73 mm to 110 mm, at least 185 mm, preferably over 210 mm, and more preferably over 230 mm,

-- with cores having the inside diameter of 111 mm to 144 mm, at least 205 mm, preferably over 210 mm, and more preferably over 230 mm,

-- with cores having th einsdie diameter of 145 mm to 180 mm, at least 210 mm, preferably over 250 mm, and more preferably 350 mm to 450 mm,

-- and with cores having the inside diameter of 181 mm to 310 mm, at least 220 mm, preferably over 250 mm, and more preferably 350 to 500 mm, but

-- at most the maximum ply width $L_{max} = (\pi) \times$ (core diameter in the specific point).

A structural ply in accordance with the invention, a paperboard core made thereof, and a method of improving the stiffness of the paperboard core are described in greater detail in the following, by way of example, with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows graphically, as a function of the winding angle α, elasticity modulus values for paperboard cores made up of different paperboard plies,

Fig. 2 illustrates the definition of the winding angle α, and

Fig. 3 illustrates the decreases in the inside diameter of a core, calculated with different winding angles a for two different types of paperboard.

DETAILED DESCRIPTION OF THE DRAWINGS

Fig. 1 enclosed is a graphical illustration, presented as a function of a winding angle a (average winding angle), of elasticity modulus values of cores manufactured by using paperboard plies in accordance with the present invention, such cores being, e.g., rotogravure cores, used in the paper, film, and textile industries, said elasticity modulus values being compared with corresponding elasticity modulus values of prior art conventional cores of the higher strength class. As discussed above, with the winding angles of about 15 - 35°, which are usually used in spiral cores, the cross machine direction elasticity modulus is of highly essential effect on the total elasticity modulus of a finished spiral core. The definition of the winding angle α (average winding angle) of a paperboard ply, in connection with the present invention, is set forth in Fig. 2. The winding angle α (average winding angle) refers to the acute angle a between the direction transverse to the paperboard core axis and the edge of the paperboard ply. In Fig. 1, the three-point dashed line refers to a typical prior art rotogravure core of the lower strength class. The uniform dashed line again refers to a typical prior art rotogravure core of the higher strength class. In this core, the paperboard used as core material is as square as possible with regard to its orientation ratio, i.e., the numeric value of the orientation ratio is small. The dotted and dashed line refers to a rotogravure core constructed of structural plies of the invention and the solid line to another rotogravure core made up of structural plies of the invention.

When reeling thin films or yarns around a spirally wound paperboard core, the material to be reeled causes a radial compression stress on the core, the inside diameter of the core becoming subject to the compression which provides a deformation therein, i.e., a decrease in the inside diameter of the core. In practical situations, this causes problems with certain types of winding chucks, when the core tends to stick thereto.

When reeling yarns around a spirally wound paperboard core or a yarn carrier, the reeling environment may still be wet, in practice. This adds to the tendency of the inside dimensions of the core to deform and the core to stick to the winding center.

We have discovered that it is possible to considerably weaken the tendency of the inside diameter of the core to decrease, by using structural plies according to the invention in constructing such cores, as can be seen from the accompanying Fig. 3.

Fig. 3 shows the decreases of the inside diameter of the core, calculated for two different paperboard grades by using different winding angles α (average winding angle). The orientation ratio of the paperboard commonly used today, which paperboard is marked with a circle, was about 1.6 in the test. The machine direction (MD) elasticity modulus was about 7000 MPa and the cross machine direction (CD) elasticity modulus about 3000 MPa. The orientation ratio of the paperboard manufactured by press drying (e.g. Condebelt paperboard), which paperboard is marked with a triangle, was about 1.8 in the test, and the machine direction (MD) elasticity modulus was about 11000 MPa, and the cross machine direction (CD) elasticity modulus about 6000 MPa.

ABSTRACT OF THE DISCLOSURE

A structural ply of a spiral paperboard core has an elasticity modulus E in the cross machine direction (CD) higher than 4500 Mpa, and an elasticity modulus E in the machine direction (MD) higher than 7500 MPa (N/mm2). Such paperboard cores may be manufactured by using, either solely or partly, these structural plies, the paperboard for making up such structural plies having been manufactured by press drying. Paperboard based on the press drying method can be manufactured, e.g., with a board machine employing the Condebelt process. The cores may be used as yarn carriers and as tubes for thin films and foils, which may be wound onto and unwound from the cores at a speed of at least about 200 meters/minute.

RULE 63 (37 C.F.R. 1.63)
DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION
IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name, and I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:
A STRUCTURAL PLY OF A PAPERBOARD CORE, A PAPERBOARD CORE MADE THEREOF, AND A METHOD OF IMPROVING THE STIFFNESS OF A PAPERBOARD CORE

The specification of which (check applicable box(s)):
☐ is attached hereto
☐ was filed on _____ as U.S. Application Serial No. _____ (Attorney Dkt. No. 38-503)
☒ was filed as PCT international application No. PCT/FI98/00061 on 23 January 1998
and (if applicable to U.S. or PCT application) No. was amended on 23 January 1998

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with 37 C.F.R. 1.56. I hereby claim foreign priority benefits under 35 U.S.C. 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed or, if no priority is claimed, before the filing date of this application:

Priority Foreign Application(s): Application Number	Country	Day/Month/Year Filed
970646	Finland	14 February 1997
(priority)	Finland	14 February 1997

I hereby claim the benefit under 35 U.S.C. §119(e) of any United States provisional application(s) listed below.
Application Number — Date/Month/Year Filed

I hereby claim the benefit under 35 U.S.C. 120/365 of all prior United States and PCT international applications listed above or below and, insofar as the subject matter of each of the claims of this application is not disclosed in such prior applications in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose material information as defined in 37 C.F.R. 1.56 which occurred between the filing date of the prior applications and the national or PCT international filing date of this application:

Prior U.S./PCT Application(s): Application Serial No.	Day/Month/Year Filed	Status: patented, pending, abandoned
PCT/FI98/00061	23 January 1998	

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon. And I hereby appoint NIXON & VANDERHYE P.C., 1100 North Glebe Rd., 8th Floor, Arlington, VA 22201-4714, telephone number (703) 816-4000 (to whom all communications are to be directed), and the following attorneys thereof (of the same address) individually and collectively my attorneys to prosecute this application and to transact all business in the Patent and Trademark Office, connected therewith and with the resulting patent: Arthur R. Crawford, 25327; Larry S. Nixon, 25640; Robert A. Vanderhye, 27076; James T. Hosmer, 30184; Robert W. Faris, 31352; Richard G. Besha, 22770; Mark E. Nusbaum, 34349; Michael J. Keenan, 32106; Bryan H. Davidson, 30251; Stanley C. Spooner, 27393; Leonard C. Mitchard, 29009; Duane M. Byers, 33363; Jeffry H. Nelson, 30481; John R. Lastova, 33149; H. Warren Burnam, Jr. 29366; Thomas E. Byrne, 32205; Mary J. Wilson, 32955; J. Scott Davidson, 33489; Alan M. Kagen, 36178; Robert A. Molan, 29834; B. J. Sadoff, 36663; James D. Berquist, 34776; Updeep S. Gill, 37334; Michael J. Shea, 34725; Donald L. Jackson, 31090; Michelle N. Lester, 32331; Frank P. Presta, 19922; Joseph S. Presta, 35329.

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